

# Uniformed Services University of the Health Sciences Department of Anesthesiology

Department of Anesthesiology  
Uniformed Services University of the Health Sciences

# Total Body Water (TBW)

- Varies with age, gender, body habitus
- 55% body weight in males
- 45% body weight in females
- 80% body weight in infants
- Less in obese: fat contains little water

# Body Water Compartments

- Intracellular water:  $\frac{2}{3}$  of TBW
- Extracellular water:  $\frac{1}{3}$  TBW
  - Extravascular water:  $\frac{3}{4}$  of extracellular water
  - Intravascular water:  $\frac{1}{4}$  of extracellular water

# Fluid and Electrolyte Regulation

- Volume Regulation
  - Arginine-Vasopressin (Antidiuretic Hormone)
  - Renin/angiotensin/aldosterone system
  - Baroreceptors in carotid arteries and aorta
  - Stretch receptors in atrium and juxtaglomerular apparatus
  - Cortisol

# Fluid and Electrolyte Regulation

- Plasma Osmolality Regulation
  - Arginine-Vasopressin (ADH)
  - Central and Peripheral osmoreceptors
- Sodium Concentration Regulation
  - Renin/angiotensin/aldosterone system
  - Macula Densa of JG apparatus

# Preoperative Evaluation of Fluid Status

- Factors to Assess:
  - mental status
  - h/o intake and output
  - blood pressure: supine *and* standing
  - heart rate
  - skin turgor
  - urinary output
  - serum electrolytes/osmolarity

# Orthostatic Hypotension

- Systolic blood pressure *decrease* of greater than 20mmHg from supine to standing
- Indicates fluid *deficit* of 6-8% body weight
  - Heart rate should increase as a compensatory measure
  - If no increase in heart rate, may indicate autonomic dysfunction or antihypertensive drug therapy

# Perioperative Fluid Requirements

- *The following factors must be taken into account:*
- Maintenance fluid requirements
- NPO and other deficits: NG suction, bowel prep
- Third space losses
- Replacement of blood loss
- Special additional losses



# Maintenance Fluid Requirements

- Insensible losses such as evaporation of water from respiratory tract, sweat, feces, urinary excretion. *Occurs continually.*
- Adults: approximately 1.5 ml/kg/hr
- “4-2-1 Rule”
  - 4 ml/kg/hr for the first 10 kg of body weight
  - 2 ml/kg/hr for the second 10 kg body weight
  - 1 ml/kg/hr subsequent kg body weight
  - Extra fluid for fever, tracheotomy, denuded surfaces

# NPO and other deficits

- NPO deficit = number of hours NPO x maintenance fluid requirement.
- Bowel prep may result in up to 1 L fluid loss.
- Measurable fluid losses, e.g. NG suctioning, vomiting, ostomy output.

# Third Space Losses

- Isotonic transfer of ECF from *functional* body fluid compartments to *non-functional* compartments.
- Depends on location and duration of surgical procedure, amount of tissue trauma, ambient temperature, room ventilation.

# Replacing Third Space Losses

- Superficial surgical trauma: 1-2 ml/kg/hr
- Minimal Surgical Trauma: 3-4 ml/kg/hr
  - head and neck, hernia, knee surgery
- Moderate Surgical Trauma: 5-6 ml/kg/hr
  - hysterectomy, chest surgery
- Severe surgical trauma: 8-10 ml/kg/hr (or more)
  - AAA repair, nephrectomy

# Blood Loss

- Replace **3 cc** of crystalloid solution per cc of blood loss (crystalloid solutions leave the intravascular space)
- When using blood products or colloids replace blood loss volume per volume

# Other factors

- Ongoing fluid losses from other sites:
  - gastric drainage
  - ostomy output
  - diarrhea
- Replace volume per volume with crystalloid solutions

# Example

- 62 y/o male, 80 kg, for hemicolectomy
- NPO after 2200, surgery at 0800, received bowel prep
- 3 hr. procedure, 500 cc blood loss
- What are his estimated intraoperative fluid requirements?

# Example (cont.)

- Fluid deficit:  $1.5 \text{ ml/kg/hr} \times 10 \text{ hrs} = 1200 \text{ ml}$   
 $+ 1000 \text{ ml for bowel prep} = 2200 \text{ ml}$   
total deficit: (Replace  $\frac{1}{2}$  first hr,  $\frac{1}{4}$  2nd hr,  $\frac{1}{4}$  3rd hour).
- Maintenance:  $1.5 \text{ ml/kg/hr} \times 3 \text{ hrs} = 360 \text{ mls}$
- Third Space Losses:  $6 \text{ ml/kg/hr} \times 3 \text{ hrs} = 1440 \text{ mls}$
- Blood Loss:  $500 \text{ ml} \times 3 = 1500 \text{ ml}$
- **Total** =  $2200 + 360 + 1440 + 1500 = 5500 \text{ mls}$



# Intravenous Fluids:

- Conventional Crystalloids
- Colloids
- Hypertonic Solutions
- Blood/blood products and blood substitutes

# Crystalloids

- Combination of water and electrolytes
  - Balanced salt solution: electrolyte composition and osmolality similar to plasma; example: lactated Ringer's, Plasmlyte, Normosol.
  - Hypotonic salt solution: electrolyte composition lower than that of plasma; example: D<sub>5</sub>W.

# Colloids

- Fluids containing molecules sufficiently large enough to prevent transfer across capillary membranes.
- Solutions stay in the space into which they are infused.
- Examples: hetastarch (Hespan), albumin, dextran.

# Hypertonic Solutions

- Fluids containing sodium concentrations greater than normal saline.
- Available in 1.8%, 3%, 5%, 7.5%, 10% solutions.
- Hyperosmolarity creates a gradient that draws water out of cells; therefore, cellular dehydration is a potential problem.

# Composition

Fluid	Osmo- lality	Na	Cl	K
<b>D5W</b>	253	0	0	0
<b>0.9NS</b>	308	154	154	0
<b>LR</b>	273	130	109	<i>4.0</i>
<b>Plasma-lyte</b>	294	140	98	<i>5.0</i>
<b>Hespan</b>	310	154	154	0
<b>5% Albumin</b>	308	145	145	0
<b>3% Saline</b>	1027	513	513	0

# Clinical Evaluation of Fluid Replacement

1. Urine Output: at least 1.0 ml/kg/hr
2. Vital Signs: BP and HR normal (How is the patient doing?)
3. Physical Assessment: Skin and mucous membranes no dry; no thirst in an awake patient
4. Invasive monitoring; CVP or PCWP may be used as a guide
5. Laboratory tests: periodic monitoring of hemoglobin and hematocrit

# Summary

- Fluid therapy is critically important during the perioperative period.
- The most important goal is to maintain hemodynamic stability and protect vital organs from hypoperfusion (heart, liver, brain, kidneys).
- All sources of fluid losses must be accounted for.
- Good fluid management goes a long way toward preventing problems.

# Transfusion Therapy

- 22 million blood components administered annually in U.S.
  - (pRBC's, whole blood, fresh frozen plasma, platelets, etc.) .
- 12,000,000 units of pRBC's annually
  - 60% of transfusions occur perioperatively.
  - responsibility of transfusing perioperatively is with the anesthesiologist.



# When is Transfusion Necessary?

- “*Transfusion Trigger*”: Hgb level at which transfusion should be given.
  - Varies with patients and procedures
- Tolerance of acute anemia depends on:
  - Maintenance of intravascular volume
  - Ability to increase cardiac output
  - Increases in 2,3-DPG to deliver more of the carried oxygen to tissues

# Oxygen Delivery

- Oxygen Delivery ( $DO_2$ ) is the oxygen that is delivered to the tissues
- $DO_2 = \text{Cardiac Output (CO)} \times \text{Oxygen Content (CaO}_2)$
- $\text{Cardiac Output (CO)} = \text{HR} \times \text{SV}$
- Oxygen Content ( $CaO_2$ ):
  - $(\text{Hgb} \times 1.39)O_2 \text{ saturation} + PaO_2(0.003)$
  - Hgb is the main determinant of oxygen content in the blood

# Oxygen Delivery (cont.)

- Therefore:  $DO_2 = HR \times SV \times CaO_2$
- If HR or SV are unable to compensate, Hgb is the major determinant factor in  $O_2$  delivery
- Healthy patients have excellent compensatory mechanisms and can tolerate Hgb levels of 7 gm/dL.
- Compromised patients may require Hgb levels above 10 gm/dL.

# Blood Groups

<u>Blood Group</u>	<u>Antigen on erythrocyte</u>	<u>Plasma Antibodies</u>	<u>Incidence</u>	
			<u>White</u>	<u>African-Americans</u>
A	A	Anti-B	40%	27%
B	B	Anti-A	11	20
AB	AB	None	4	4
O	None	Anti-A Anti-B	45	49
Rh	Rh		42	17

# Cross Match

- Major:
  - Donor's erythrocytes incubated with recipients plasma
- Minor:
  - Donor's plasma incubated with recipients erythrocytes
- Agglutination:
  - Occurs if either is incompatible
- Type Specific:
  - Only ABO-Rh determined; chance of hemolytic reaction is 1:1000 with TS blood

# Type and Screen

- Donated blood that has been tested for ABO/Rh antigens and screened for common antibodies (not mixed with recipient blood).
  - Used when usage of blood is unlikely, but needs to be available (hysterectomy).
  - Allows blood to be available for other patients.
  - Chance of hemolytic reaction: 1:10,000.

# Component Therapy

- A unit of whole blood is divided into components; Allows prolonged storage and specific treatment of underlying problem with increased efficiency:
  - packed red blood cells (pRBC's)
  - platelet concentrate
  - fresh frozen plasma (contains all clotting factors)
  - cryoprecipitate (contains factors VIII and fibrinogen; used in Von Willebrand's disease)
  - albumin
  - plasma protein fraction
  - leukocyte poor blood
  - factor VIII
  - antibody concentrates

# Packed Red Blood Cells

- 1 unit = 250 ml. Hct. = 70-80%.
- 1 unit pRBC's raises Hgb 1 gm/dL.
- Patient hemoglobin levels down to 7 gm/dL are generally tolerated if intravascular volume is maintained.
- Mixed with saline: LR has Calcium which may cause clotting if mixed with pRBC's.



# Platelet Concentrate

- Treatment of thrombocytopenia
- Intraoperatively used if platelet count drops below 50,000 cells-mm<sup>3</sup> (lab analysis).
- 1 unit of platelets increases platelet count 5000-10000 cells-mm<sup>3</sup>.
- Risks:
  - Sensitization due to HLA on platelets
  - Viral transmission

# Fresh Frozen Plasma

- Plasma from whole blood frozen within 6 hours of collection.
  - Contains coagulation factors except platelets
  - Used for treatment of isolated factor deficiencies, reversal of Coumadin effect, TTP, etc.
  - Used when PT and PTT are  $>1.5$  normal
- Risks:
  - Viral transmission
  - Allergy

# Complications of Blood Therapy

- Transfusion Reactions:
  - Febrile; most common, usually controlled by slowing infusion and giving antipyretics
  - Allergic; increased body temp., pruritis, urticaria. Rx: antihistamine, discontinuation. Examination of plasma and urine for free hemoglobin helps rule out hemolytic reactions.

# Complications of Blood Therapy (cont.)

- Hemolytic:
  - Wrong blood type administered (oops).
  - Activation of complement system leads to intravascular hemolysis, spontaneous hemorrhage.
  - Signs: hypotension, fever, chills, dyspnea, skin flushing, substernal pain. Signs are easily masked by general anesthesia.
  - Free Hgb in plasma or urine
  - Acute renal failure
  - Disseminated Intravascular Coagulation (DIC)

# Treatment of Acute Hemolytic Reactions

- Immediate discontinuation of blood products
- Maintenance of urine output with crystalloid infusions
- Administration of mannitol or Furosemide for diuretic effect

# Complications (cont.)

- Transmission of Viral Diseases:
  - Hepatitis C; 1:30,000 per unit
  - Hepatitis B; 1:200,000 per unit
  - HIV; 1:450,000-1:600,000 per unit
  - 22 day window for HIV infection and test detection
  - CMV may be the most common agent transmitted, but only effects immunocompromised patients
  - Parasitic and bacterial transmission very low

# Other Complications

- Decreased 2,3-DPG with storage: ? Significance
- Citrate: metabolism to bicarbonate; Calcium binding
- Microaggregates (platelets, leukocytes): micropore filters controversial
- Hypothermia: warmers used to prevent
- Coagulation disorders: massive transfusion (>10 units) may lead to dilution of platelets and factor V and VIII.
- DIC: uncontrolled activation of coagulation system

# Autologous Blood

- Pre-donation of patient's own blood prior to elective surgery
- 1 unit donated every 4 days (up to 3 units)
- Last unit donated at least 72 hrs prior to surgery
- Reduces chance of hemolytic reactions and transmission of blood-bourne diseases
- Not desirable for compromised patients



# Administering Blood Products

- Consent necessary for elective transfusion
- Unit is checked by 2 people for Unit #, patient ID, expiration date, physical appearance.
- pRBC's are mixed with saline solution (not LR)
- Products are warmed mechanically and given slowly if condition permits
- Close observation of patient for signs of complications
- If complications suspected, infusion discontinued, blood bank notified, proper steps taken.

# Alternatives to Blood Products

- Autotransfusion
- Blood substitutes

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# Autotransfusion

- Commonly known as “Cell-saver”
- Allows collection of blood during surgery for re-administration
- RBC’s centrifuged from plasma
- Effective when  $> 1000\text{ml}$  are collected

# Blood Substitutes

- Experimental oxygen-carrying solutions: developed to decrease dependence on human blood products
- Military battlefield usage initial goal
- Multiple approaches:
  - Outdated human Hgb reconstituted in solution
  - Genetically engineered/bovine Hgb in solution
  - Liposome-encapsulated Hgb
  - Perfluorocarbons

# Blood Substitutes (cont.)

- Potential Advantages:
  - No cross-match requirements
  - Long-term shelf storage
  - No blood-bourne transmission
  - Rapid restoration of oxygen delivery in traumatized patients
  - Easy access to product (available on ambulances, field hospitals, hospital ships)

# Blood Substitutes (cont.)

- Potential Disadvantages:
  - Undesirable hemodynamic effects:
    - Mean arterial pressure and pulmonary artery pressure increases
  - Short half-life in bloodstream (24 hrs)
  - Still in clinical trials, unproven efficacy
  - High cost

# Transfusion Therapy Summary

- Decision to transfuse involves many factors
- Availability of component factors allows treatment of specific deficiency
- Risks of transfusion must be understood and explained to patients
- Vigilance necessary when transfusing any blood product